THE IMPACT OF HIV/AIDS ON MORTALITY AT A SOUTH AFRICAN PLATINUM MINE

Robert Joseph Dowdeswell

A research report submitted to The Faculty of Health Sciences,

University of the Witwatersrand, Johannesburg,

in partial fulfillment of the requirements for the degree

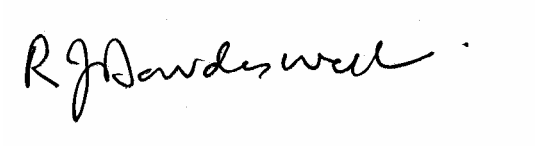
of

Master of Science in Medicine in the field of Epidemiology and Biostatistics

Rustenburg, 2007

DECLARATION

I, Robert Joseph Dowdeswell, declare that this research report is my own work. It is being submitted for the degree of Master of Science in Medicine in the branch of Epidemiology and Biostatistics in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other university.



24th May, 2007

ABSTRACT

Background: There is a paucity of empirical data on the impact of HIV/AIDS on mortality in the mining industry in the pre-ART era. Such data will provide a baseline against which the efficacy of antiretroviral treatment can be measured into the future.

Objectives: To measure all-cause mortality in a population of platinum miners between 1992 and 2002, the impact of HIV/AIDS on mortality in this group and to determine the pattern of other cause-specific mortality.

Methods: This was a primary analysis of mortality in an open cohort of male semi- and unskilled workers at a platinum mine. Using Poisson regression, all-cause, HIV/AIDS-related and other cause-specific mortality rates and rate ratios were calculated by age and calendar year.

Results: There were 1986 deaths in the cohort of 29954 subjects who contributed 200657 person years of follow up over the 11 year period of the study. Crude all-cause mortality increased from a base of 5.1 per 1000 person years at risk (pyar) (95% CI 4.2-6.2) in 1992 to 20.4 per 1000 pyar (95% CI 18.3-22.8) in 2002. Age-adjusted all-cause mortality increased more than three-fold from 1992 to 2002 (RR 3.2, 95% CI 2.5-4.0). The excess mortality was attributed to HIV/AIDS-related deaths which increased from 0% in 1992-1994 to 5.1% of total deaths in 1995 and reached 63.3 % of deaths in 2002. Mortality due to other communicable diseases, non-communicable diseases and injuries remained stable throughout the study period.

Conclusion: The impact of the HIV/AIDS epidemic on mortality in this group of platinum mine workers has been profound and comparable to that experienced by the general South African population. The data reported here provide a baseline to measure the impact of antiretroviral treatment on the future course of mortality due to the epidemic.

ACKNOWLEDGEMENTS

I would like to express my gratitude to the following people and organisation for their contribution towards the completion of this study:

Professor Jill Murray, for agreeing to supervise my project and for her enthusiastic guidance and encouragement;

Dr Pam Sonnenberg , for co-supervising and her assistance with the statistical analysis;

Anglo Platinum, for allowing me to do this research.

TABLE OF CONTENTS

DECLARATION ii

ABSTRACT III

ACKNOWLEDGEMENTS IV

TABLE OF CONTENTS V

LIST OF FIGURES VII

LIST OF TABLES VIII

1.0 INTRODUCTION 1

1.1 BACKGROUND 1

1.2 THE IMPACT OF HIV/AIDS ON ADULT MORTALITY 2

1.3 THE IMPACT OF HIV/AIDS ON MORTALITY IN SUB-SAHARAN AFRICA 2

1.4 THE IMPACT OF HIV/AIDS ON MORTALITY IN SOUTH AFRICA 3

1.5 THE IMPACT OF HIV/AIDS ON THE SOUTH AFRICAN MINING INDUSTRY 5

2.0 MOTIVATION FOR THE STUDY 6

3.0 STUDY OBJECTIVES 6

4.0 METHODS 7

4.1 STUDY SETTING 7

4.2 STUDY DESIGN 7

4.3 MINE POPULATION AND STUDY SUBJECT SELECTION 7

4.3.1 Mine Population 7

4.3.2 Study Subjects 8

4.3.3 Study Variables 8

4.3.4 Medical Boarding 8

4.4 Determining Vital Status 9
4.5 Data Sources Used to Determine Cause of Death 9
4.5.1 Hospital Death Register 9
4.5.2 Medical Boarding Records 9
4.5.3 Medical Records 10
4.6 ICD-10 Coding of Deaths 10
4.6.1 HIV/AIDS Related Deaths 10
4.6.2 Coding Ill-Defined Causes of Death 11
4.7 Burden of Disease Classification of Mortality 11
4.8 Data Analysis 11
4.9 Ethics Approval 12
5.0 RESULTS 12
5.1 Mine Population Characteristics and Outcomes 12
5.2 All-Cause Mortality 15
5.3 Cause-Specific Mortality 20
5.3.1 HIV/AIDS Related Mortality Rates 21
5.3.2 Non-HIV/AIDS Related Mortality Rates 24
6.0 DISCUSSION 26
6.1 All-Cause Mortality 26
6.2 Cause-Specific Mortality 28
6.2.1 HIV/AIDS Related Mortality 28
6.2.2 Non-HIV/AIDS Related Mortality 28
6.3 Strengths of the Study 29
6.4 Limitations of the Study 30
6.5 Conclusion 31
7.0 APPENDIX A 32
8.0 REFERENCES 36

List of Figures

Figure 1. Crude all-cause mortality (rate per 1000 pyar, 95% confidence intervals) by calendar year: 1992-2002 15

Figure 2. All-cause age-specific mortality rates by calendar year: 1992-2002 17

Figure 3. All-cause age-specific mortality rates compared to South African national rates: 1997-2002 19

Figure 4. Crude cause-specific mortality rates by calendar year: 1992-2002 20

Figure 5. HIV/AIDS-related deaths as percentage of total deaths, compared to adult deaths predicted from ASSA600[24] 22

LIST OF TABLES

Table 1. Mine population characteristics and outcomes 13

Table 2. Deaths by year of entry to cohort 13

Table 3. Deaths, including post-medical boarding, by calendar year 14

Table 4. Medical boarding cases, rates and rate ratios 14

Table 5. Crude and age-standardised all-cause mortality rates by calendar year 16

Table 6. All-cause age-specific mortality rates and rate ratios by age: 1992-2002 16

Table 7. Crude and age-adjusted all-cause mortality rate ratios by calendar year 18

Table 8. Crude cause-specific mortality rates 21

Table 9. HIV/AIDS mortality rates and rate ratios by age 22

Table 10. Crude and age-adjusted HIV/AIDS mortality rate ratios by calendar year 23

Table 11. Number of HIV/AIDS deaths by ICD-10 codes 24

Table 12. Causes of death by National Burden of Diseases classification 25

1.0 INTRODUCTION

1.1 BACKGROUND

In South Africa the first cases of acquired immunodeficiency syndrome (AIDS) were diagnosed in 1982, heralding the beginning of the first epidemic that was largely confined to homosexual men.[1, 2] By January 1988 a total of 98 cases had been diagnosed, 86% of which occurred in homosexual males.[3] Over the following decade there was slower spread to the heterosexual population resulting in a second epidemic similar in demographic characteristics and scope to that of other African countries.[2, 4, 5]

From the outset though, documenting the extent and impact of the epidemic was complicated by issues of confidentiality, individual versus community interests, the socio-political circumstances peculiar to South Africa and the intense stigmatisation associated with the disease.[3] Furthermore, until recently the national death registration system was not capable of providing vital statistics for the majority of the population.[6]

Initially, systematic national surveillance of AIDS was implemented through a system of voluntary anonymous reporting of AIDS cases by doctors under the auspices of the Department of National Health and Population Development according to procedures adopted by the World Health Organisation (WHO).[7] This approach was clearly subject to underreporting and, as tests for HIV antibodies were developed and became generally available, voluntary anonymous reporting was replaced in 1990 by a programme of human immunodeficiency virus (HIV) seroprevalence surveillance based on annual surveys on women attending antenatal clinics across the county.[7-10]

By 1995 it was estimated that 1.7 million sexually active adults were infected with HIV based on antenatal seroprevalence data and in 2000 the WHO estimated that South Africa had more people living with the HIV than any other country in the world.[9, 11]

1.2 THE IMPACT OF HIV/AIDS ON ADULT MORTALITY

Prior to the advent of antiretroviral treatment (ART) HIV infection was invariably fatal with a median survival time from seroconversion of about 9 years.[12] The impact of HIV/AIDS on adult mortality has been illustrated by two types of studies: (1) those in which the HIV status of individuals is known, thereby allowing direct comparisons to be made between infected and uninfected individuals; and (2) studies of national level statistics, where, although HIV status of individuals is unknown, strong indirect evidence is provided by mortality time trends and characteristic age patterns consistent with a major impact of the HIV epidemic.[13]

1.3 THE IMPACT OF HIV/AIDS ON MORTALITY IN SUB-SAHARAN AFRICA

Porter and Zaba reviewed the empirical data from studies conducted in the community and other settings in which HIV status was known to provide direct evidence that the rising mortality observed in the developing world was caused by HIV.[14] Estimates of survival at 5 years after seroconversion in two African cohorts were very similar at 79% and 77% with a median survival estimated at 8.6 years.[12, 15] Direct data from community based studies showed mortality rates for uninfected individuals in four sub-Saharan countries of 2-5 deaths per 1000 person years for those in their teens and twenties, increasing to 5-17 per 1000 person years for those in thirties and forties.[15-18] Rates for infected individuals, when standardised for age, were considerably higher and more variable: mortality rates for infected individuals in their teens varied between 25-45 deaths per 1000 person years, rising to 70-120, 90-150 and 90-200 respectively for those in their twenties, thirties and forties.

In one study of factory workers in Tanzania during 1991 to 1996, overall mortality rates were 9.0 and 7.8 per 1000 person years for men and women respectively.[19] Mortality attributable to HIV infection, estimated at 5-6 and 4-5 per 1000 person years for men and

women respectively, was considerably lower than found in the other sub-Saharan studies quoted above, possibly associated with a “healthy worker” effect.

Blacker reviewed adult mortality trends in sub-Saharan countries with significant levels of HIV prevalence using data sources other than those that collect information on HIV status (national population censuses and sample surveys, Demographic and Health Surveys (DHS), vital registration and longitudinal surveillance systems).[20] Census and survey data from Kenya, Malawi and Zimbabwe showed increasing mortality in the 1990s, reversing previous downward trends. DHS data for over 20 sub-Saharan countries showed that most had increasing mortality which was steepest in eastern and southern Africa, with high HIV prevalence rates. Death registration in Zimbabwe, which has appreciable levels of HIV, showed increasing adult mortality: age-specific death rates for males aged 25 to 49, based on official death registrations with adjustment for completeness, increased at least two-fold between 1982 and 1995 with increases of 3.3, 4.1 and 3.0 times for age groups 30-34, 35-39 and 40-44 respectively.[21] During the 15-year period 1982-1997 the conditional probability of death by age 60, given survival to age 15, rose from 0.31 to 0.65 for males.

1.4 THE IMPACT OF HIV/AIDS ON MORTALITY IN SOUTH AFRICA

There are currently no published empirical data from South African studies in the general population on survival after HIV seroconversion or comparisons of mortality comparing HIV-positive with HIV-negative subjects. There are however a number of community based studies that show increasing adult mortality during the 1990s.

Tollman *et. al.* reported a relative increase in mortality over three years from 1992 to 1995 observed at the Agincourt demographic and health surveillance field site in the Bushbuckridge district where all reported deaths were subject to verbal autopsy.[22]

Mortality increase at age 24-49 was 23% for both sexes combined with increased death rates due to AIDS, pulmonary tuberculosis and chronic diarrhoea.

Hosegood et. al. reported a sudden and massive increase in adult mortality in a demographic surveillance study that included verbal autopsy interviews in rural northern Kwa-Zulu Natal in the late 1990s.[23] By 2000 AIDS with or without tuberculosis was the leading cause of death in the study population accounting for 73 and 61% of female and male deaths respectively at ages 15-44 years and the probability of dying between the ages 15 and 60 was 58% for women and 75% for men.

Empirical data obtained from routine cause of death data compiled and reported by Stats SA and the Population Register administered by the Department of Home Affairs revealed that there was a steady increase in adult mortality during the 1990s.[24] Mortality of women aged 25-29 years was 3.5 times higher in 1999/2000 than in 1985. Mortality in young men aged 30-39 doubled over the same period. Comparing these data to projections based on the ASSA600 AIDS and demographic model it was estimated that about 40% of adult deaths aged 15-49 that occurred in the year 2000 were due to HIV/AIDS and that about 20% of all adult deaths were due to AIDS. [24, 25] Further projections from this study showed that without treatment to prevent AIDS, the number of AIDS deaths can be expected to increase within the next 10 years to more than double the number of deaths due to all other causes, resulting in 5 to 7 million cumulative AIDS deaths in South Africa by 2010.

Although the completeness of registration of deaths had improved substantially by 1997 (80% of all deaths to males and 78% of all deaths to females registered[26]), it has been suggested that the official mortality statistics for South Africa underreport HIV/AIDS deaths with only 39% of HIV/AIDS deaths been reported as such.[27]

1.5 THE IMPACT OF HIV/AIDS ON THE SOUTH AFRICAN MINING INDUSTRY

Williams and Campbell noted that the most important factors leading to severe HIV epidemics in Africa - social and political instability, disruption of social support mechanisms and family structures, migrancy, high rates of other sexually transmitted diseases which accelerate the transmission of the HIV virus and opportunistic infections, especially tuberculosis and pneumonia, which increase mortality and morbidity among HIV-positive people - characterise the lives of many of the workers employed on South African mines.[28] It may be expected therefore that the impact of HIV/AIDS in the mining industry may be higher than the official death statistics reported at the national level.

The prevalence of HIV infection in gold miners was reported to be between 0.02% and 3.76% in 1986, depending on geographic area of origin.[29] More recent surveys reported a prevalence of HIV infection of 18.0% in the mining industry, the highest in the industrial sectors surveyed.[30] In 2002 prevalence rates for HIV infection at a platinum mine were estimated to range between 20.4% and 28.8%, with the highest rates amongst the lower job categories.[31]

As experienced in the public and private sectors, HIV infection has placed a significant burden on health services in the mining industry. In the gold mining sector hospitalisation and mortality incident rate ratios in a cohort of 1792 HIV-infected miners were 2.9 and 9.2 respectively compared to HIV-negative miners in a 12 month prospective study where the prevalence of HIV infection was 24%.[32] A recent study on survival in a HIV seroconversion cohort of South African gold miners showed that the survival pattern was similar to that seen in the West before antiretroviral therapy was available.[33]

The economic impact of HIV/AIDS can be considered in terms of direct and indirect costs. In 1999 it was estimated that the direct costs of an average set of benefits (including medical scheme costs) was expected to double for many schemes by 2005, and triple by 2010.[34] It was further estimated that indirect costs (loss of turnover, recruitment/training, sick/compassionate leave, motivation/productivity loss, legal costs, and management and labour meetings) could add another 10% to the remuneration budget of a typical manufacturing company by 2005, and 15% by 2010.

2.0 MOTIVATION FOR THE STUDY

By 2003, the year in which ART programmes were first rolled out, the HIV/AIDS epidemic in South Africa had matured into the "sick and dying" phase. Although high levels of HIV prevalence have been documented amongst miners, there is little published data on the impact of HIV/AIDS on mortality in the mining industry. While it remains to be seen to what extent the course of the epidemic will be altered by the advent of ART, a review of empirical data on HIV/AIDS mortality will provide policy makers and service providers, including mine management, trade unions, government and local health authorities and non-governmental organisations, with a baseline against which the impact of ART can be measured into the future.

3.0 STUDY OBJECTIVES

The objectives of the study are:

- to measure the trend of all-cause mortality in a population of platinum miners between 1 January 1992 and 31 December 2002;
- to measure the impact of HIV/AIDS on mortality between 1 January 1992 and 31 December 2002.

- to determine other cause-specific mortality according to the South African National Burden of Disease Study classification between 1 January 1992 and 31 December 2002.

4.0 METHODS

4.1 STUDY SETTING

The setting for the study was a large platinum mine in North West Province, South Africa, employing about 22000 people in 1992.

4.2 STUDY DESIGN

The design was an open cohort comprising all employees working at the mine between 1 January 1992 and 31 December 2002 and entailed a primary analysis of mortality.

4.3 MINE POPULATION AND STUDY SUBJECT SELECTION

4.3.1 MINE POPULATION

Mine personnel records were used to construct a database containing demographic data on all employees who worked at the mine between 1 January 1992 and 31 December 2002. This required the merging of an archived personnel database that was operational until April 2001 with the current personnel database. In both systems an employee could have multiple company numbers as a result of promotion and/or re-employment. The data were filtered using national identity and passport numbers to identify duplicate and/or multiple records for single individuals. Where duplicate or multiple records were identified, the individual's record was consolidated under the last or current company number.

The mine employees were classified into two groups as either (1) semiskilled or unskilled workers comprising predominantly migrant underground miners, labourers and surface plant workers (SUS); or (2) skilled workers comprising artisans and officials (SOF).

4.3.2 STUDY SUBJECTS

Subjects selected for study were all male SUS employees who worked at the mine between 1 January 1992 and 31 December 2002. This group was chosen for study as it represented the majority of the mine population (82.7%) and because their medical records were available at the mine hospital (where they received free medical aid) for establishing cause of death.

4.3.3 STUDY VARIABLES

The following variables were extracted from the database for each subject:

- study number – a unique number randomly assigned for the study
- date of birth
- date employed
- date employment terminated
- variable indicating reason for termination of employment (death, medical boarding or other)

4.3.4 MEDICAL BOARDING

As a condition of employment all SUS employees are members of a provident fund co-funded by the company. Membership of the provident fund provides a death benefit in the form of a lump sum payable to the employee's next-of-kin in the event of the employee dying within 12 months of being medically boarded for a life-threatening illness ("terminal illness"). Personnel records relating to medical boarding did not discriminate between medical boarding classified as "terminal illness" or due to other causes. For the purposes of this study it was therefore assumed that all medical boarding was due to "terminal illness" and the date of termination (censoring) of all medically boarded employees was

extended by 12 months as these employees effectively remained at risk and under observation while eligible for the provident fund death benefit.

4.4 DETERMINING VITAL STATUS

Vital status was determined by identifying all in-service deaths recorded in the personnel database and deaths recorded by the provident fund within one year of termination of employment following medical boarding.

4.5 DATA SOURCES USED TO DETERMINE CAUSE OF DEATH

The following sources were used to determine cause of death:

4.5.1 HOSPITAL DEATH REGISTER

The mine hospital maintains a register of deaths of employees occurring in the hospital. Deaths that occur outside of the hospital (e.g. due to motor vehicle accidents, or deaths of medically boarded employees) are also recorded in the register when reported to mine authorities.

The death register records cause of death based on the death certificate (original death certificates were not available to the investigator), clinical diagnosis of the terminal illness, or mode of death in the case of unnatural deaths (e.g. motor vehicle accident, mine accident, suicide).

4.5.2 MEDICAL BOARDING RECORDS

Mine procedure for medical boarding is a formal process involving the employee, his/her union representative, mine management and the medical service. Records for this procedure include a medical report that is submitted to the insurer. In the case of death following medical boarding, the diagnosis recorded in the medical report to the insurer

was assumed to be the cause of death, unless information to the contrary (e.g. death from accidental cause) was found.

4.5.3 MEDICAL RECORDS

Where no cause of death could be found from the above sources, or where the cause of death was ill-defined (e.g. “natural causes”, “shock”), the clinical records at the mine hospital were reviewed (if available).

4.6 ICD-10 CODING OF DEATHS

For the purposes of this study the investigator coded the cause of all deaths according to the tenth revision of the International Classification of Diseases, (ICD-10).[35]

4.6.1 HIV/AIDS RELATED DEATHS

It is standard practice in the mine health service to establish HIV status in all patients presenting with clinical features suggestive of HIV/AIDS-related disease (subject to informed consent with pre- and post-test counselling). Terminology used to record HIV/AIDS-related deaths however was not standardised and included the terms AIDS, “AIDS-related”, “immune compromised” and “retroviral disease”. All causes of death recorded in the hospital death register or medical boarding records that included these terms were recorded as HIV/AIDS-related and assigned ICD-10 codes B20 to B23 where sufficient clinical detail was provided, or B24 as default (unspecified human immunodeficiency virus [HIV] disease). Where medical records were reviewed deaths were coded as HIV/AIDS-related if a positive HIV test result was documented in the record and clinical findings consistent with WHO criteria for staging HIV-1 infections were present.[36]

4.6.2 CODING ILL-DEFINED CAUSES OF DEATH

For non-accidental deaths where there was insufficient information to assign a specific code, or where clinical records could not be found, ICD-10 code R99 (other ill-defined and unspecified cause of mortality) was assigned.

For accidental deaths where information on mode of death was not available, ICD code Y34 (unspecified event, undetermined intent) was assigned.

4.7 BURDEN OF DISEASE CLASSIFICATION OF MORTALITY

For the purpose of determining cause-specific mortality, ICD-10 codes were grouped according to the South African National Burden of Disease (NBD) list developed for the South African NBD study as described by Bradshaw. [37] In this system mortality is divided into three broad groups of causes of death as follows (Appendix A):

- Group I - pre-transitional causes (communicable diseases, maternal causes, perinatal conditions and nutritional deficiencies);
- Group II - non-communicable causes;
- Group III - injuries.

Although HIV/AIDS is part of Group I, it is reported separately here as it is the subject of this study.

4.8 DATA ANALYSIS

After assigning study numbers and deleting the employee company number field to ensure confidentiality, data were analysed using Stata software, version 8.[38] Standard descriptive statistics were used to describe the demographic characteristics of the study population. Individual records were expanded into person years at risk (pyar) by calendar year (1992 to 2002) and 5-year age categories (<25, 25-29, 30-34, 35-39, 40-44, 45-49,

50-54, 55+). All-cause, HIV/AIDS-related and other cause-specific mortality rates and rate ratios were calculated by age and calendar year. Analyses used Poisson regression, with adjustment for age as a time varying co-variate.

4.9 ETHICS APPROVAL

The study protocol was approved by the University of the Witwatersrand Committee for Research on Human Subjects (Medical) (R14/49, protocol number M041028, 1/11/04).

5.0 RESULTS

5.1 MINE POPULATION CHARACTERISTICS AND OUTCOMES

The personnel database contained records for 36215 employees who had worked on the mine between 1 January 1992 and 31 December 2002 (Table 1). Male subjects comprised the majority of the mine population (n = 35181, 97.1%). A total of 1914 deaths occurred in-service (males 1908, all-cause death rate 8.4 per 1000 pyar; females 6, all-cause death rate 1.5 per 1000 pyar). There were 29954 male SUS employees (82.7% of total population) with 1809 in-service and 177 post-medical boarding deaths (total deaths 1986, all-cause mortality rate 9.0 per 1000 pyar) and 351 female SUS employees (1.0% of total population) with 4 in-service deaths (all-cause mortality rate 2.7 per 1000 pyar). There were 5227 male SOF employees (14.4% of total population) with 99 in-service deaths (all-cause mortality rate 3.8 per 1000 pyar) and 683 female SOF category employees (1.9% of total population) with 2 in-service deaths (all-cause mortality rate 0.8 per 1000 pyar). All further analyses refer to the 29953 male SUS workers.

Table 1. Mine population characteristics and outcomes

	Total population	SUS				SOF			
		Males		Females		Males		Females	
n (%)	36 215	29 954	(82.7)	351	(1.0)	5 227	(14.4)	683	(1.9)
Age, mean (sd)		35.4	(8.5)	32.9	(9.1)	33.3	(10.3)	29.4	(8.9)
pyar (%)	230 509	200 657	(87.1)	1 471	(0.6)	25 964	(11.3)	2 417	(1.1)
Deaths (%)	2 091	1986*	(95.0)	4	(0.2)	99	(4.7)	2	(0.1)
Mortality rate	9.1	9.9		0.02		0.4		0.01	
Medical boarding cases (%)	833	797	(95.7)	5	(0.6)	31	(3.7)	0	
Medical boarding rate	3.6	4.0		0.02		0.1			

SUS, semiskilled and unskilled workers; SOF, skilled workers and officials

*Includes 177 deaths after medical boarding

(%), of total population. Rates are per 1000 pyar

Employees in service or enrolled in 1992 made up the majority of the cohort (67.2%) and accounted for 77.8% of deaths (Table 2). There were 1809 in-service deaths and a further 177 deaths occurred within 12 months of medical boarding, bringing the total number of deaths to 1986.

Table 2. Deaths by year of entry to cohort

	Total cohort		Deaths					
			In-service		Post med board		Total	
Year	N	(%)*	n	(%)**	n	(%)**	n	(%)**
1992	20117	67.2	1402	70.6	143	7.2	1545	77.8
1993	1730	5.8	89	4.5	8	0.4	97	4.9
1994	1323	4.4	76	3.8	5	0.3	81	4.1
1995	1001	3.3	63	3.2	4	0.2	67	3.4
1996	1978	6.6	102	5.1	8	0.4	110	5.5
1997	604	2.0	26	1.3	2	0.1	28	1.4
1998	439	1.5	18	0.9	3	0.2	21	1.1
1999	667	2.2	10	0.5	3	0.2	13	0.7
2000	474	1.6	12	0.6	1	0.1	13	0.7
2001	505	1.7	6	0.3	0	0.0	6	0.3
2002	1116	3.7	5	0.3	0	0.0	5	0.3
Total	29954	100.0	1809	91.1	177	8.9	1986	100.0

* % of total cohort (29954)

** % of total deaths (1986)

Med board, medical boarding

The number of deaths by calendar year is shown in Table 3. The number of deaths in medically boarded cases increased sharply from 23 (1.2%) in 2000 to 83 (4.2%) in 2002. Although the absolute number of in-service deaths peaked in 2000 (259, 13.0%) the total

number of deaths continued to increase each year to the end of the study because of deaths in medically boarded subjects.

Table 3. Deaths, including post-medical boarding, by calendar year

	Deaths					
	Post med board		In-service		Total	
Year	n	(%)*	n	(%)	n	(%)
1992	0	0.0	97	4.9	97	4.9
1993	2	0.1	113	5.7	115	5.8
1994	2	0.1	120	6.0	122	6.1
1995	1	0.1	117	5.9	118	5.9
1996	3	0.2	130	6.5	133	6.7
1997	0	0.0	155	7.8	155	7.8
1998	0	0.0	167	8.4	167	8.4
1999	2	0.1	176	8.9	178	9.0
2000	23	1.2	259	13.0	282	14.2
2001	61	3.1	234	11.8	295	14.9
2002	83	4.2	241	12.1	324	16.3
Totals	177	8.9	1809	91.1	1986	100.0

* % of total deaths (1986)
med board, medical boarding

The rate of medical boarding cases remained relatively constant from 1992 to 1999 but then increased significantly from 2000 (4.5 per 1000 pyar, age-adjusted RR 1.6, 95% CI 1.1-2.4) over the last three years to 2002 (13.8 per 1000 pyar, adjusted RR 4.6, 95% CI 3.3-6.6) (Table 4).

Table 4. Medical boarding cases, rates and rate ratios

		Medical		Unadjusted		Adjusted*	
Year	pyar	boarding	Rate	RR	95%CI	RR	95%CI
1992	19009	37	1.9	1		1	
1993	18695	55	2.9	1.5	1.0 - 2.3	1.4	0.9 - 2.2
1994	19395	33	1.7	0.9	0.5 - 1.4	0.8	0.5 - 1.3
1995	19456	33	1.7	0.9	0.5 - 1.4	0.7	0.5 - 1.2
1996	19049	64	3.4	1.7	1.2 - 2.6	1.4	0.9 - 2.1
1997	19254	62	3.2	1.7	1.1 - 2.5	1.3	0.9 - 2.0
1998	18527	60	3.2	1.7	1.1 - 2.5	1.3	0.8 - 1.9
1999	17852	31	1.7	0.9	0.6 - 1.4	0.7	0.4 - 1.1
2000	17251	77	4.5	2.3	1.5 - 3.4	1.6	1.1 - 2.4
2001	16296	126	7.7	4.0	2.8 - 5.7	2.7	1.9 - 3.9
2002	15873	219	13.8	7.1	5.0 - 10.0	4.6	3.3 - 6.6
Totals	200657	797	4.0				

*Adjusted for age; pyar, person years at risk; RR, rate ratio.
(Rates are per 1000 pyar)

5.2 ALL-CAUSE MORTALITY

Crude all-cause mortality from 1992 to 2002 is shown in Figure 1. Mortality rates were relatively stable between 1992 to 1995 (5.1-6.1 per 1000 pyar), increasing to 10.0 in 1999 and to 20.4 per 1000 pyar by 2002.

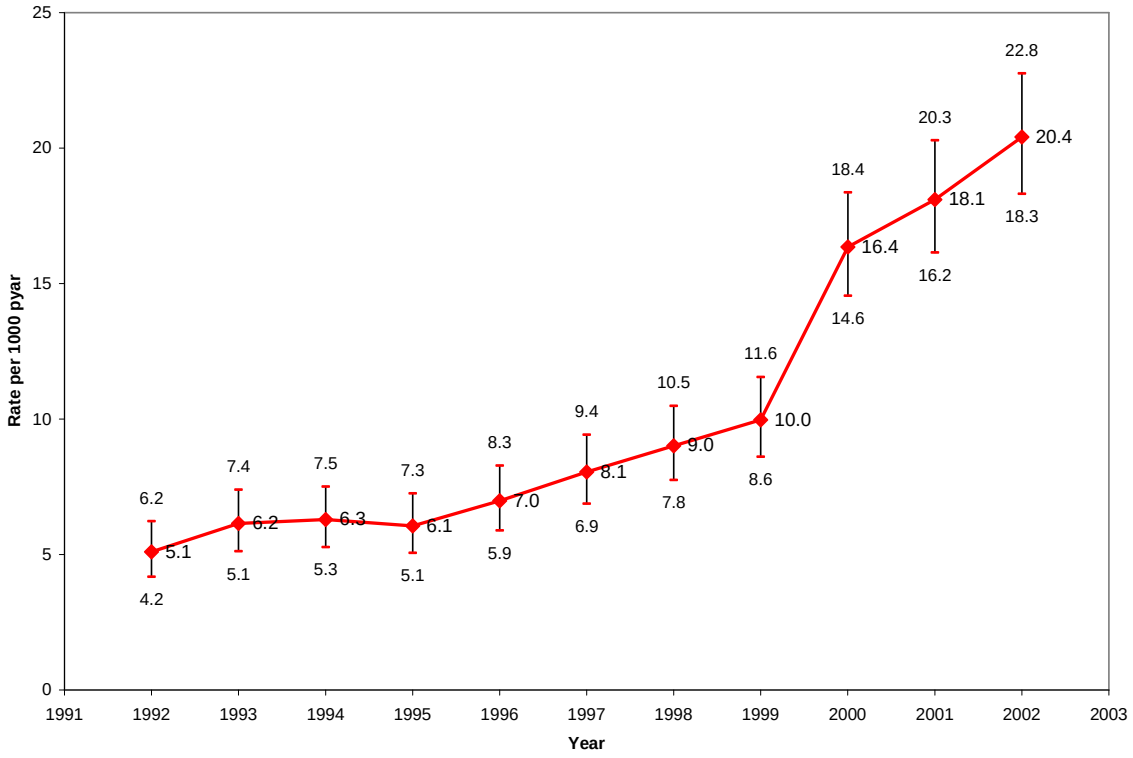


Figure 1. Crude all-cause mortality (rate per 1000 pyar, 95% confidence intervals) by calendar year: 1992-2002

Crude all-cause mortality rates, standardised for age, are shown in Table 5. Age-standardisation resulted in slightly higher rates compared to crude rates for years 1992 to 1996 and thereafter slightly lower rates (2002, 18.7 versus 20.4).

Table 5. Crude and age-standardised all-cause mortality rates by calendar year

			Crude rates		Age-standardised	
Year	pyar	Deaths	Rate	95% CI	Rate	95% CI
1992	19009	97	5.1	4.2 - 6.2	5.7	4.5 - 6.9
1993	18695	115	6.2	5.1 - 7.4	6.6	5.4 - 7.9
1994	19395	122	6.3	5.3 - 7.5	6.9	5.6 - 8.1
1995	19456	118	6.1	5.1 - 7.3	6.4	5.2 - 7.5
1996	19049	133	7.0	5.9 - 8.3	7.1	5.9 - 8.3
1997	19254	155	8.1	6.9 - 9.4	8.0	6.7 - 9.3
1998	18527	167	9.0	7.8 - 10.5	8.7	7.4 - 10.1
1999	17852	178	10.0	8.6 - 11.6	9.6	8.2 - 11.0
2000	17251	282	16.4	14.6 - 18.4	15.5	13.7 - 17.4
2001	16296	295	18.1	16.2 - 20.3	17.0	14.9 - 19.0
2002	15873	324	20.4	18.3 - 22.8	18.7	16.5 - 20.8
	200657	1986	9.9	9.5 10.3		

pyar, person years at risk; CI, confidence interval
(Rates are per 1000 pyar)

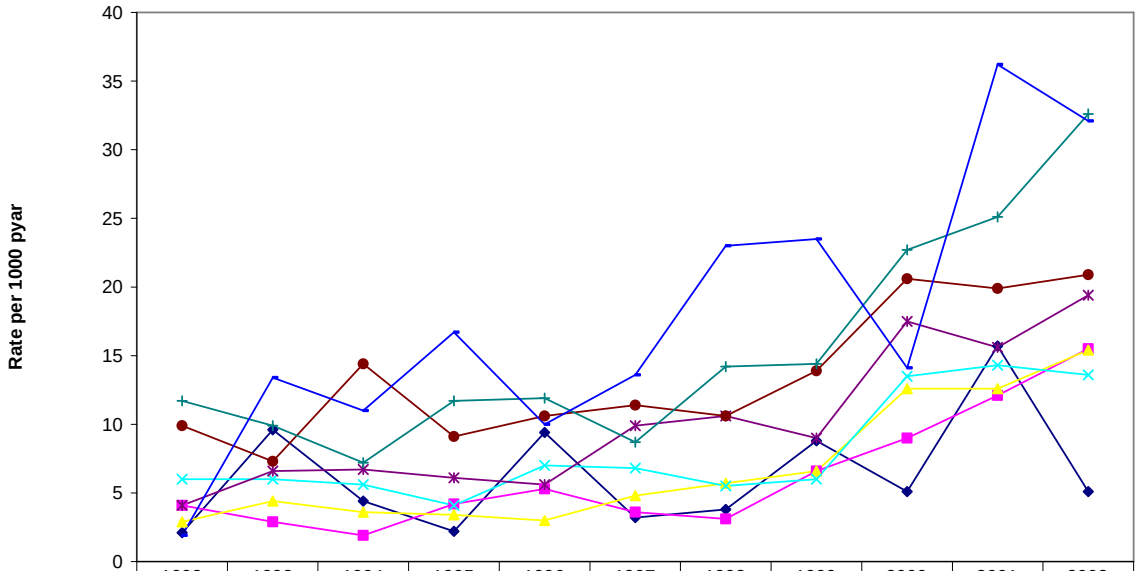
All-cause age-specific mortality rates and rate ratios are shown in Table 6. All-cause mortality increased with age from 5.9 /1000 pyar for under 25 years to 18.8/1000 pyar for 55 years and older. Mortality rate ratios for age groups 25 to 39 years were not significantly increased compared to under 25 year olds (0.9-1.2) but increased significantly and progressively for age groups over 40 years.

Table 6. All-cause age-specific mortality rates and rate ratios by age: 1992-2002

			Crude rates		Rate ratios	
Age	pyar	Deaths	Rate	95% CI	RR	95% CI
<25	5060	30	5.9	4.1 - 8.5	1	
25-29	15205	84	5.5	4.5 - 6.8	0.9	0.6 - 1.4
30-34	31982	173	5.4	4.7 - 6.3	0.9	0.6 - 1.3
35-39	48128	348	7.2	6.5 - 8	1.2	0.8 - 1.8
40-44	45153	477	10.6	9.7 - 11.6	1.8	1.2 - 2.6
45-49	28669	413	14.4	13.1 - 15.9	2.4	1.7 - 3.5
50-55	16762	279	16.6	14.8 - 18.7	2.8	1.9 - 4.1
>55	9698	182	18.8	16.2 - 21.7	3.2	2.2 - 4.7
Totals	200657	1986	9.9	9.5 - 10.3		

pyar, person years at risk; RR, rate ratio; CI, confidence interval
(Rates are per 1000 pyar)

All-cause age-specific mortality rates by calendar year are shown in Figure 2. Mortality rates increased over the study period for all age groups over 25 years of age.



	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
<25	2.1	9.6	4.4	2.2	9.4	3.2	3.8	8.8	5.1	15.7	5.1
25-29	4.1	2.9	1.9	4.2	5.3	3.6	3.1	6.6	9	12.1	15.5
30-34	2.9	4.4	3.6	3.4	3	4.8	5.7	6.6	12.6	12.6	15.4
35-39	6	6	5.6	4.1	7	6.8	5.5	6	13.5	14.3	13.6
40-44	4.1	6.6	6.7	6.1	5.6	9.9	10.6	9	17.5	15.6	19.4
45-49	9.9	7.3	14.4	9.1	10.6	11.4	10.6	13.9	20.6	19.9	20.9
50-54	11.7	9.9	7.2	11.7	11.9	8.7	14.2	14.4	22.7	25.1	32.6
55+	1.9	13.4	11	16.7	10	13.6	23	23.5	14.1	36.2	32.1

Figure 2. All-cause age-specific mortality rates by calendar year: 1992-2002

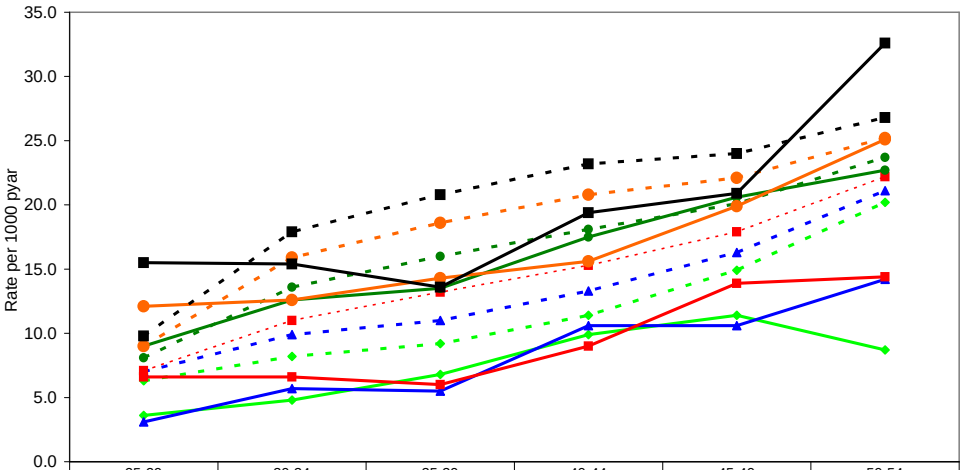
Crude and age-adjusted all-cause mortality rates and rate ratios by calendar year are shown in Table 7. Unadjusted rate ratios for years 1993 to 1995 were not significantly different from 1992 baseline but thereafter increased significantly from 1996 (RR 1.4, 95% CI 1.1-1.8) to 2002 (RR 4.0, 95% CI 3.2-5.0). After adjusting for age, estimates of mortality rate ratios were slightly decreased and reached significance in 1997 compared to1996 for unadjusted rates.

Table 7. Crude and age-adjusted all-cause mortality rate ratios by calendar year

				Unadjusted		Adjusted for age	
Year	pyar	Deaths	Rate	RR	95%CI	RR	95%CI
1992	19009	97	5.1	1		1	
1993	18695	115	6.2	1.2	0.9 - 1.6	1.2	0.9 - 1.5
1994	19395	122	6.3	1.2	0.9 - 1.6	1.2	0.9 - 1.5
1995	19456	118	6.1	1.2	0.9 - 1.6	1.1	0.8 - 1.4
1996	19049	133	7.0	1.4	1.1 - 1.8	1.2	1.0 - 1.6
1997	19254	155	8.1	1.6	1.2 - 2.0	1.4	1.1 - 1.8
1998	18527	167	9.0	1.8	1.4 - 2.3	1.5	1.2 - 2.0
1999	17852	178	10.0	2.0	1.5 - 2.5	1.7	1.3 - 2.1
2000	17251	282	16.4	3.2	2.5 - 4.0	2.7	2.1 - 3.4
2001	16296	295	18.1	3.5	2.8 - 4.5	2.9	2.3 - 3.6
2002	15873	324	20.4	4.0	3.2 - 5.0	3.2	2.5 - 4.0

pyar, person years at risk; RR, rate ratio; CI, confidence interval.
(Rates are per 1000 pyar)

Figure 3 shows all-cause age-specific (25-54 years) mortality rates for years 1997-2002 (solid lines) with South African rates for males (dashed lines) for comparison.[26] In general the observed trend in age-specific all-cause mortality rates was similar to the reported national rates for males.



	25-29	30-34	35-39	40-44	45-49	50-54
1997	3.6	4.8	6.8	9.9	11.4	8.7
SA 1997	6.3	8.2	9.2	11.4	14.9	20.2
1998	3.1	5.7	5.5	10.6	10.6	14.2
SA 1998	7.0	9.9	11.0	13.3	16.3	21.1
1999	6.6	6.6	6.0	9.0	13.9	14.4
SA 1999	7.1	11.0	13.2	15.3	17.9	22.2
2000	9.0	12.6	13.5	17.5	20.6	22.7
SA 2000	8.1	13.6	16.0	18.1	20.1	23.7
2001	12.1	12.6	14.3	15.6	19.9	25.1
SA 2001	9.0	15.9	18.6	20.8	22.1	25.2
2002	15.5	15.4	13.6	19.4	20.9	32.6
SA 2002	9.8	17.9	20.8	23.2	24.0	26.8

Figure 3. All-cause age-specific mortality rates compared to South African national rates: 1997-2002

5.3 CAUSE-SPECIFIC MORTALITY

Crude cause-specific mortality rates by calendar year for HIV/AIDS, NBD groups and unknown causes are shown in Figure 4 and Table 8.

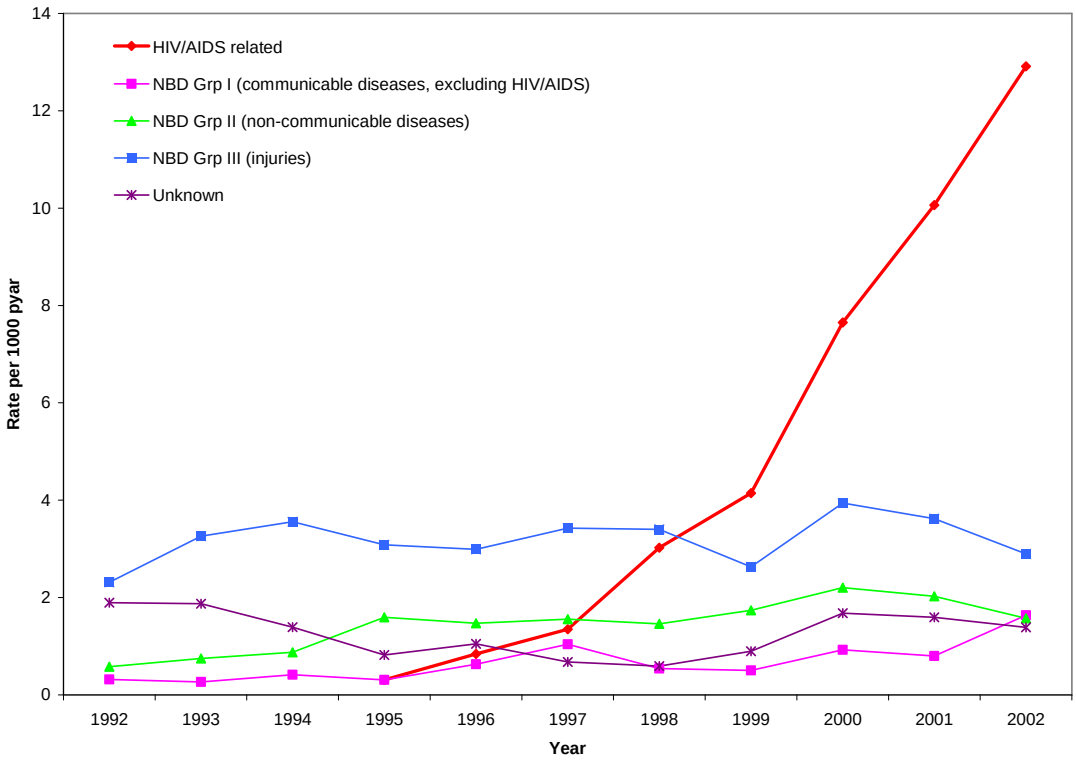


Figure 4. Crude cause-specific mortality rates by calendar year: 1992-2002

Table 8. Crude cause-specific mortality rates

		Total	HIV/AIDS		NBD Grp I		NBD Grp II		NBD Grp III		Unknown	
Year	pyar	deaths	n	Rate	n	Rate	n	Rate	n	Rate	n	Rate
1992	19009	97	0	-	6	0.3	11	0.6	44	2.3	36	1.9
1993	18695	115	0	-	5	0.3	14	0.7	61	3.3	35	1.9
1994	19395	122	0	-	8	0.4	17	0.9	69	3.6	27	1.4
1995	19456	118	6	0.3	6	0.3	31	1.6	60	3.1	16	0.8
1996	19049	133	16	0.8	12	0.6	28	1.5	57	3.0	20	1.0
1997	19254	155	26	1.4	20	1.0	30	1.6	66	3.4	13	0.7
1998	18527	167	56	3.0	10	0.5	27	1.5	63	3.4	11	0.6
1999	17852	178	74	4.1	9	0.5	31	1.7	47	2.6	16	0.9
2000	17251	282	132	7.7	16	0.9	38	2.2	68	3.9	29	1.7
2001	16296	295	164	10.1	13	0.8	33	2.0	59	3.6	26	1.6
2002	15873	324	205	12.9	26	1.6	25	1.6	46	2.9	22	1.4
Totals	200657	1986	679	4.7	131	0.7	285	1.4	640	3.2	251	1.3

pyar, person years at risk
(Rates are per 1000 pyar)

5.3.1 HIV/AIDS RELATED MORTALITY RATES

No HIV/AIDS-related deaths occurred in subjects under the age of 25 years. There were no HIV/AIDS-related deaths reported in 1992, 1993 or 1994. HIV/AIDS-related deaths, first recorded in 1995 (n=6, rate 0.4 per 1000 pyar), increased progressively to 2002 (n= 205, rate 12.9 per 1000 pyar) (p for trend < 0.01). Figure 5 shows HIV/AIDS-related deaths as a percentage of total deaths from all causes compared to adult deaths estimated from the ASSA600 model.[24] HIV/AIDS-related deaths in this study increased rapidly from 5.1% of total deaths in 1995 to 63.3% in 2002 at a rate similar to that predicted by the ASSA600 model.

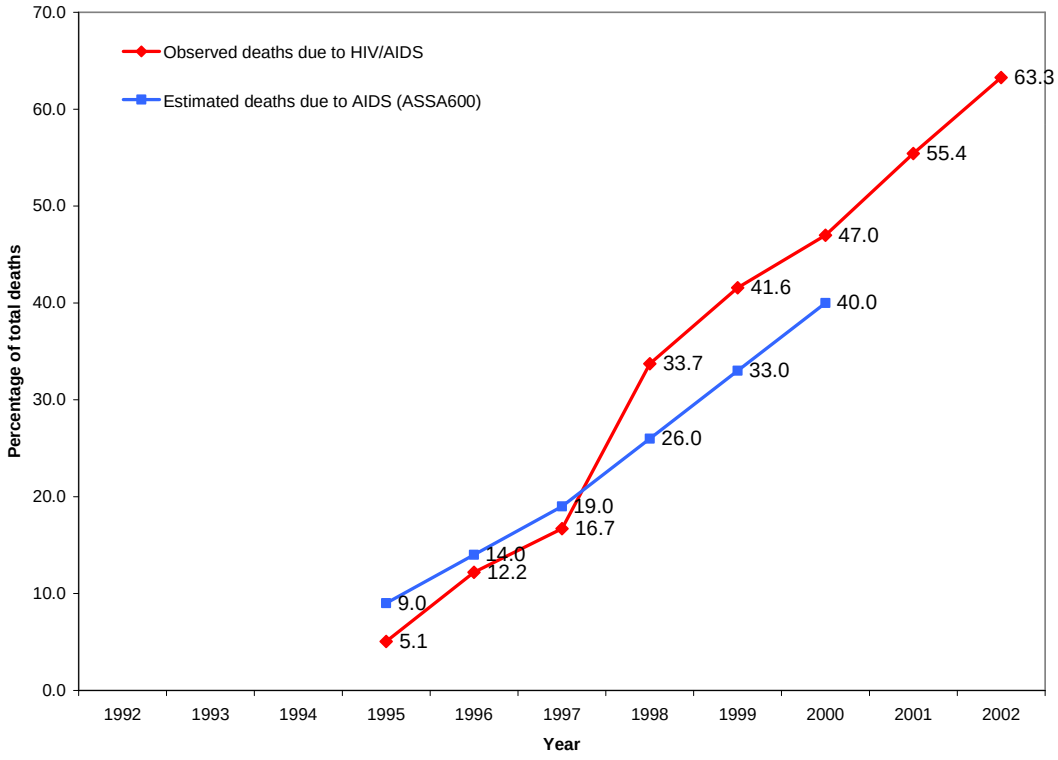


Figure 5. HIV/AIDS-related deaths as percentage of total deaths, compared to adult deaths predicted from ASSA600[24]

HIV/AIDS-related mortality rates and rate ratios by age are shown in Table 9. HIV/AIDS-related mortality rates increased across age groups from 2.0 per 1000 pyar for age 25-29 to 8.2 per 1000 pyar for age 55 years and older. However, compared to those aged 25-29 years, the increase in rate ratios was significant only for age 40 and older.

Table 9. HIV/AIDS mortality rates and rate ratios by age

Age*	pyar	Deaths	Rate	RR	95% CI
25-29	9683	19	2.0	1	
30-34	18100	53	2.9	1.5	0.9 - 2.5
35-39	32628	101	3.1	1.6	1.0 - 2.6
40-44	35480	181	5.1	2.6	1.6 - 4.2
45-49	23273	154	6.6	3.4	2.1 - 5.4
50-54	12854	107	8.3	4.2	2.6 - 6.9
55+	7839	64	8.2	4.2	2.5 - 6.9
Totals	143558	679	4.7		

*Note: there were no AIDS deaths in subjects <25 years of age
pyar, person years at risk; RR, rate ratio; CI, confidence interval
(Rates are per 1000 pyar)

Unadjusted rate ratios for crude HIV/AIDS-related mortality increased significantly from 2.7 (95% CI 1.1-7.0) in 1996 to 41.9 (95% CI 18.6-94.3) in 2002 (Table 10) and remained highly significant after adjusting for age (using 1995 as a baseline).

Table 10. Crude and age-adjusted HIV/AIDS mortality rate ratios by calendar year

			Unadjusted			Adjusted*	
Year	pyar	Deaths	Rate	RR	95%CI	RR	95%CI
1992	19009	0	-	-	- -	-	- -
1993	18695	0	-	-	- -	-	- -
1994	19395	0	-	-	- -	-	- -
1995	19456	6	0.3	1		1	
1996	19049	16	0.8	2.7	1.1 - 7.0	2.7	1.1 - 6.9
1997	19254	26	1.4	4.4	1.8 - 10.6	4.3	1.8 - 10.4
1998	18527	56	3.0	9.8	4.2 - 22.7	9.4	4.1 - 21.9
1999	17852	74	4.1	13.4	5.8 - 30.9	12.7	5.5 - 29.2
2000	17251	132	7.7	24.8	10.9 - 56.2	23.0	10.1 - 52.0
2001	16296	164	10.1	32.6	14.5 - 73.7	29.5	13.1 - 66.7
2002	15873	205	12.9	41.9	18.6 - 94.3	37.4	16.6 - 84.6
Totals	143558	679					

* Adjusted for age.

pyar, person years at risk; RR, rate ratio; CI, confidence interval.

(Rates are per 1000 pyar)

The distribution of HIV/AIDS-related deaths by ICD-10 codes is shown in Table 11. ICD-10 code B24 (unspecified HIV disease) accounted for 283 (41.7%) of the HIV/AIDS-related deaths. Of the remaining, the majority (348, 51.3%) were due to ICD-10 code B20 (infectious and parasitic diseases) of which 168 (24.7%) were due to tuberculosis (data not shown).

Table 11. Number of HIV/AIDS deaths by ICD-10 codes

	Total		Year							
ICD 10 Code	n	(%)	1995	1996	1997	1998	1999	2000	2001	2002
B20	348	51.3	3	13	21	39	42	68	76	86
B21	9	1.3				2		2	2	3
B22	9	1.3				4	1	3		1
B23	29	4.3						10	1	18
B24	283	41.7	3	3	4	11	31	49	85	97
C46	1	0.1			1					
Total	679		6	16	26	56	74	132	164	205

B20: HIV disease resulting in infectious and parasitic diseases
B21: HIV disease resulting in malignant neoplasms
B22: HIV disease resulting in other specified diseases
B23: HIV disease resulting in other conditions
B24: Unspecified human immunodeficiency virus [HIV] disease
C46: Kaposi's sarcoma

5.3.2 NON-HIV/AIDS RELATED MORTALITY RATES

Mortality rates for NBD group I conditions remained relatively unchanged throughout the study period but increased significantly in 2002 (n=26, rate 1.6 per 1000 pyar, RR 3.3, 95% CI 1.3-8.0). Mortality rates for NBD group II conditions were stable between 1992 and 1994 but thereafter fluctuated, reaching a peak in 2000 (n=38, rate 2.2, RR=2.7, 95% CI 1.4-5.3). There was no significant trend in death rates or rate ratios for NBD group III conditions.

Causes of death (other than HIV/AIDS-related) for NBD group I, II and III, by calendar year, are summarised in Table 12. In NBD group I (communicable diseases, excluding HIV/AIDS-related causes), tuberculosis (42.7%) and respiratory infections (40.5%) accounted for the majority (83.2%) of deaths (Table 12(a)).

Table 12. Causes of death by National Burden of Diseases classification

(a) National Burden of Disease Group I: Communicable diseases

	n	(%)	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Tuberculosis	56	42.7	2	3	1	5	4	12	3	4	6	6	10
Respiratory infections	53	40.5	2	2	5	1	7	6	6	3	4	4	13
Septicaemia	8	6.1						1	1	1	3	1	1
Diarrhoeal diseases	6	4.6	1				1				1	1	2
Bacterial menigitis	6	4.6			2					1	2	1	
Other causes	2	1.5	1	0	0	0	0	1	0	0	0	0	0
Total	131		6	5	8	6	12	20	10	9	16	13	26

(b) National Burden of Disease Group II: Non-communicable diseases

	n	(%)	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Malignant neoplasms	109	38.246	7	11	8	19	7	9	5	7	14	11	11
Cardiovascular	76	26.667	3	3	2	2	9	8	8	17	12	6	6
Digestive	35	12.281	1	0	2	4	4	4	5	3	5	5	2
Genito-urinary	22	7.7193			3	2	3	3	5	1	3	2	
Respiratory	18	6.3158	0	0	2	4	2	2	1	0	2	3	2
Nervous system disorders	10	3.5088	0	0	0	0	2	3	1	0	0	4	0
Diabetes mellitus/endocrine	15	5.2632	0	0	0	0	1	1	2	3	2	2	4
Total	285		11	14	17	31	28	30	27	31	38	33	25

(c) National Burden of Disease Group III: Injuries

	n	(%)	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Road traffic accidents	253	39.531	21	22	33	22	22	26	24	20	27	28	8
Homicide	183	28.594	6	16	11	17	18	13	27	18	23	15	19
Mining accidents	102	15.938	10	11	13	11	6	12	7	4	8	7	13
Other unintentional	36	5.625	0	5	7	4	5	8	1	1	2	2	1
Suicide and self-inflicted	53	8.2813	2	2	4	5	5	7	3	5	8	6	6
Undetermined	13	2.0313	5	5	1	1	1						
Total	640		44	61	69	60	57	66	62	48	68	58	47

The majority of deaths in NBD group II (non-communicable diseases) were due to malignant neoplasm (38.2%) and cardiovascular conditions (26.7%) (Table 12(b)). Nearly a third of deaths over the 11-year period were due to injuries (640/1986) (Table 12(c)). Road traffic accidents (39.5%) and homicides (28.6%) accounted for the majority of these deaths. There were 102 mining accidents, which contributed 15.9% of deaths due to injury and 5.1% (102/1986) of all deaths.

A specific cause of death could not be determined in 251 of the 1346 deaths (13.3%) attributed to natural causes (NBD groups I and II) because of insufficient clinical information and/or unavailability of records. In the case of unnatural causes of death (NBD group III) the mode of death could not be determined in 13 of the 640 deaths (2.0%).

6.0 DISCUSSION

This study provides insight into the evolution and impact of the HIV/AIDS epidemic from before the first deaths due to HIV/AIDS were recorded until antiretroviral therapy first became available to a large cohort of male workers at a platinum mine in North West Province. Ascertainment of vital status was complete for subjects while in service at the mine and included deaths that occurred within 12 months after employment was terminated for medical reasons. The specific cause was known for the majority of deaths (86.7%).

6.1 ALL-CAUSE MORTALITY

All-cause age-adjusted mortality remained relatively stable from 1992 to 1995 but thereafter increased significantly reaching 20.4 per 1000 pyar by 2002. There is surprisingly little data from South Africa with which this finding can be compared.

Tollman *et. al.* found that all-cause mortality for adult males age 20-49 years increased by 25% in roughly 2 years between the period 1992-1993 and 1994-1995 in the Bushbuckridge area.[22] This increase was not statistically significant and was very similar to the increase in all-cause mortality in the present study (24.6%; from 5.7% in 1992 to 7.1% in 1996). The slight difference may be explained by differences in age distribution and by the fact that the platinum miners had free access to comprehensive health care services.

Hosegood *et. al.* reported a sharp increase in all-cause adult mortality in rural KwaZulu Natal for the year 2000 compared to the period 1982-1997 determined by the orphanhood method applied to their study population and the 1996 Census of South Africa.[23] Mortality rates in their study were considerably higher (46 to 152%) compared to the corresponding year of the present study. This finding is perhaps not entirely unexpected

considering that all-cause mortality in KwaZulu Natal has been shown to be higher than in all the other provinces.[39]

Dorrington et. al., using death registration data reported to the Department of Home Affairs and taking into account completeness of registration of deaths, estimated that premature adult mortality (indicated by the probability of a 15 year old dying before the age of 60) would begin increasing from 1996 and more than double to as high as 80% by 2010.[24] While the format of these data does not allow direct comparison to the present study, the year of onset of increasing all-cause mortality was very similar to that found in the present study (1996 versus 1997).

More recent death registration data published by Stats SA[26] allows direct comparison of national all-cause age-specific mortality with the present study for the period 1997 to 2002 (Figure 3). In general, mortality rates increased in a similar pattern over increasing age groups. However, except for age group 50-54 years in 2002, annual age-specific mortality rates observed in the present study (solid lines) were generally lower than reported for the general population (dashed lines). This finding could be explained by the fact that the population studied was a working population with free access to comprehensive medical services as well as the healthy worker effect

In the present study age-specific mortality (Table 6) showed a significant increase for age groups 40-44 and older only. It has been shown that median survival is strongly associated with age at HIV seroconversion: 11.5 years for those aged 15-24 at seroconversion versus 6.3 years for those older than 45 years.[33]

All-cause age-specific mortality observed in the present study for 25 to 49 year olds in 2002 was very similar to that reported for males in Zimbabwe in 1995.[21]

6.2 CAUSE-SPECIFIC MORTALITY

6.2.1 HIV/AIDS RELATED MORTALITY

The increase in all-cause mortality was entirely attributable to HIV/AIDS-related deaths (Figure 4). Given that HIV seroprevalence rates in gold miners were as low as 0.02% in 1986[29] and that by 2002 the seroprevalence rate for HIV in the study population was 24% (data for platinum miners not available before 2002), and taking into consideration that median time from HIV seroconversion to death before the advent of generally available antiretroviral therapy (i.e. the time period of this study) is about 10 years[12, 33], this finding is not unexpected.

By the year 2001 HIV/AIDS-related mortality exceeded all other causes of death combined. For years 1998 to 2000 HIV/AIDS-related deaths as a percentage of total deaths in the present study were higher than estimated by the ASSA600 demographic model for the general population (Figure 5).[24] Given that mortality rates for women are higher than for men in the ASSA600 model, the difference between HIV/AIDS-related compared to total deaths for men between the present study and that estimated by the ASSA600 model may even be greater.

More than half of the HIV/AIDS-related deaths (51.3 %) were due to infectious diseases, predominantly tuberculosis and pneumonia. Tuberculosis accounted for 168 of the HIV/AIDS-related deaths. Cause specific HIV/AIDS deaths were not analysed in more detail as this was not the objective of the research.

6.2.2 NON-HIV/AIDS RELATED MORTALITY

Mortality rates classified according to NBD groups, excluding HIV/AIDS-related deaths, showed no systematic trend over the study period (Figure 4). This finding is surprising considering that a number of demographic models (including the ASSA600 model) used to estimate the AIDS epidemic assume a decline in non-AIDS mortality and supports the

opinion of Dorrington *et. al.* that adult mortality from non-AIDS causes has probably not declined over the past 15-20 years.[40]

Mortality rates and rate ratios for NBD group I conditions (infectious diseases excluding HIV/AIDS) remained unchanged over the study period except for the last year (RR 3.3, 95% CI 1.3-8.0). Respiratory infections, septicaemia, diarrhoeal diseases and bacterial meningitis were all recorded more frequently from 1997 onwards (Table 12(a)). These conditions have been recognised to contribute to misclassification of HIV/AIDS-related deaths and may account for some misclassification of HIV/AIDS-related deaths in the present study in cases where individuals refused HIV testing.[27]

Mortality rates and rate ratios for NBD group II conditions (non-communicable diseases) showed somewhat more fluctuation being significantly increased above the 1992 baseline for four of the last six years of the study. Again, it is possible that some misclassification of HIV/AIDS-related deaths occurred due to misreporting cause of death.

Mortality rates and rate ratios for NBD group III conditions (injuries) remained unchanged over the study period except for a slight rise in 2000 (RR 1.6, 95% CI 1.1-2.4). This is a disappointing finding as safety, both on the job and at home, is an issue taken very seriously within the mining industry.

6.3 STRENGTHS OF THE STUDY

The strengths of this study include the following:

- there was no possibility of selection bias as the entire population of male semi- and unskilled workers, representing more than 80% of the total mine population, was studied;
- deaths within one year of medical boarding were included in the study – without follow-up of medically boarded subjects the deaths due to HIV/AIDS-related

conditions would have been significantly underestimated as increasing numbers of workers elected to spend their last months at home with their families;

- the study period was over a long time period from before the first HIV/AIDS-related deaths were recorded up until ART became freely available.

- the study took into account possible confounding by age, through presenting age-standardised rates and age-adjusted RRs.

6.4 LIMITATIONS OF THE STUDY

Limitations of the study include:

- the fact that cause of death was unknown in 251 (18.6%) cases of NBD group I and II conditions and 13 cases (2.0 %) of NBD group III conditions. However, these deaths were relatively evenly distributed over the study period (Figure 4) and are unlikely to have introduced significant bias although it is possible that some of these deaths could have been HIV/AIDS-related;

- the possibility of misclassification bias due to incorrect classification of cause of death.[27]

- the findings of the study may be an underestimate of the true HIV/AIDS mortality rate because cause of death was not available in 251 men.

- the findings of the study may not be generalisable to the non-working portion of the South African population. The healthy worker effect and access to good quality medical services might reduce the impact of HIV/AIDS on mortality.

6.5 CONCLUSION

The impact of HIV/AIDS on mortality was striking. This study provides important new empirical data on the evolution and natural history of the HIV/AIDS epidemic in the mining industry prior to the roll out of freely available antiretroviral treatment and provides a baseline for assessing the long-term efficacy of antiretroviral treatment into the future.

7.0 APPENDIX A

South African Burden of Disease List

Category		SABOD	#	SA BOD list	ICD-10 CODES
I				**Communicable**	**A00-A99, B00-B99, C46, D50-D53, D64, E00-E02, E40-E46, E50-E64, G00, G03, H65-H66, J00-J22, J90, N70-N73, O00-O99, P00-P96**
I	**A**			**Infectious and Parasitic**	**A00-A99, B00-B99, C46, G00, G03, J90, N70-N73**
I	A	ZA	1	Tuberculosis	A15-A19, B90, J90
I	A	ZA	2	STDs excluding HIV	A50-A64, N70-N73
I	A	ZA	2a	Syphilis	A50-A53
I	A	ZA	2b	Other STDs	A54-A64, N70-N73
I	A	ZA	3	HIV/AIDS	B20-B24, C46
I	A	ZA	4	Diarrhoeal Diseases	A00-A04, A06-A09
I	A	ZA	5	Childhood Vaccine Preventable) cluster	A33-A37, A80, B03, B05-B06, B91
I	A	ZA	5a	Pertussis	A37
I	A	ZA	5b	Polio	A80, B91
I	A	ZA	5c	Diptheria	A36
I	A	ZA	5d	Measles	B05
I	A	ZA	5e	Tetanus	A33-A35
I	A	ZA	5f	Rubella	B06
I	A	ZA	6	Bacterial Meningitis and meningococcemia	A39, G00, G03
I	A	ZA	7	Hepatitis	B15-B19
I	A	ZA	8	Malaria	B50-B54
I	A	ZA	9	Schistosomiasis and other tropical diseases	B55-B56, B65, B74
I	A	ZA	10	Leprosy	A30, B92
I	A	ZA	11	Intestinal Parasites (nematodes)	B76-B81
I	A	ZA	12	Septicemia	A40-A41
I	A	ZA	13	Other infectious and parasitic	A05, A20-A28, A31 ,A32, A38, A42-A49, A65-A69, A70-A74, A75-A79, A81-A89, A90-A99, B00-B02, B04, B07-B09, B25-B34, B35-B49, B57-B64, B66-B73, B75, B82-B89, B94-B99
I	**B**			**Respiratory infections**	**J00-J06, J10-22, H65-H66**
I	B	ZA	14	Lower respiratory infections	J10-J18, J20-J22
I	B	ZA	15	Upper respiratory infections	J00-J06
I	B	ZA	16	Otitis media	H65-H66
I	**C**			**Maternal Conditions**	**O00-O99**
I	C	ZA	17	Maternal haemorrhaoe	O20, O44-O46, O67, O72
I	C	ZA	18	Maternal sepsis	O85-O86
I	C	ZA	19	Hypertension in pregnancy	O10-O16
I	C	ZA	20	Obstructed Labour	O64-O66
I	C	ZA	21	Abortion	O00-O08
I	C	ZA	22	Other maternal	O21-O29, O30-O43, O47-O48, O60-O63,O68-O71, O73-O75, O80-O84, O87-O92, O95-O99
I	**0**			**Perinatal Conditions**	**P00-P96**
I	0	ZA	23	Low birth weight	P05-P07, P22
I	0	ZA	24	Birth asphyxia and trauma	P03, P10-P15, P20-P21
I	0	ZA	25	Other perinatal respiratory conditions	P23-P28
I	0	ZA	26	Neonatal infections	P35-P39
I	0	ZA	27	Other perinatal	P00-P02, P04, P08, P29, P50-P61, P70-P94, P96
				Ill defined	P95

I	**E**			**Nutritional deficiencies**	**D50-D53 D64 E00-E02 E40-E46 E50-E64**
I	E	ZA	28	Protein-calorie malnutrition	E40-E46
I	E	ZA	29	Deficiency anemia's	D50-D53, D64
I	E	ZA	30	Other nutritional deficiencies including pellagra and vitamin A deficiency	E00-E02, E50-E64
II				**Non-Communicable Disease**	**C00-C45, C47-C97, D00-D48, D55-D63, D65-D89, E03-E07, E10-E14, E15-E34, E65-E90, F00-F99, G04-G99, H00-H63, H68-H95, I00-I99, J30-J89, J92-J98, K00-K93, L00-L98, M00-M99, N00-N64, N75-N99, Q00-Q99, R00-R95**
II	**F**			**Malignant Neoplasms**	**C00-C45, C47-C97**
II	F	ZA	31	Mouth and Oropharynx	C00-C14
II	F	ZA	32	Esophagus	C15
II	F	ZA	33	Stomach	C16
II	F	ZA	34	Colo-rectal	C18-C21
II	F	ZA	35	Liver	C22
II	F	ZA	36	Pancreas	C25
II	F	ZA	37	Larynx	C32
II	F	ZA	38	Trachea/bronchi/lung	C33-C34
II	F	ZA	39	Bone and connective tissue	C40-C41, C4,7 C49
II	F	ZA	40	Melanoma	C43
II	F	ZA	41	Other skin cancer	C44
II	F	ZA	42	Breast	C50
II	F	ZA	43	Cervix	C53
II	F	ZA	44	Corpus uteri	C54, C55
II	F	ZA	45	Ovary	C56
II	F	ZA	46	Prostate	C61
II	F	ZA	47	Bladder	C67
II	F	ZA	48	Kidney	C64-C66, C68
II	F	ZA	49	Brain	C71
II	F	ZA	50	Lymphoma + multiple myeloma	C81-C90, C96
II	F	ZA	51	Leukemia	C91-C95
II	F	ZA	52	Other malignant neoplasms	C17, C23-C24, C26, C30-C31, C37-C39, C45, C48, C51-C52, C57-C58, C60, C62-C63, C69-C70, C72-C75
				III defined cancers	C76-CBO, C97
II	**G**	**ZA**	**53**	**Other neoplasms**	**D00-D48**
II	**H**	**ZA**	**54**	**Diabetes Mellitus**	**E10-E14**
II	**I**			**Endocrine and metabolic disorders**	**D55-D63, D65-D89, E03-E07, E15-E34, E65-89**
II	I	ZA	55	Albinism	E70.3
II	I	ZA	56	Other endocrine and metabolic	D55-D63, D65-D89, E03-E07, E15-E16, E20-E34, E65-E68, E71- E89
II	**J**			**Mental disorders**	**F10-F99**
II	J	ZA	57	Alcohol dependence	F10
II	J	ZA	58	Drug use	F11-F16, F18-F19
II	J	ZA	59	Schizophrenia	F20-F29
II	J	ZA	60	Unipolar	F32-F33
II	J	ZA	61	Bipolar	F30-F31
II	J	ZA	62	Anorexia nervosa	F50
II	J	ZA	63	Neurotic disorders	F40-F42
II	J	ZA	64	Hyperkinetic Syndrome of childhood	F90
II	J	ZA	65	Adjustment reaction (PTSS)	F43
II	J	ZA	66	Mental Disability	F70-F79
II	J	ZA	67	Other mental disorders	F17, F34-39, F44-F48, F51-F59, F60-F69, F80-F89, F91-F98, F99

II	**K**			**Nervous system disorders**	**F01-F09, G03-G99**
II	K	ZA	68	Alzheimer and other dementias	F01-F09, G30-G31
II	K	ZA	69	Parkinson's disease	G20-G21
II	K	ZA	70	Multiple sclerosis	G35
II	K	ZA	71	Epilepsv	G40-G41
II	K	ZA	72	Encephalitis and brain abscess	G04, G06, G09
II	K	ZA	73	Other nervous system disorders	G08, G10-G12, G23-25, G36-G37, G43-G47, G50-G58, G60-G64, G70-G72, G80-G83, G90-G98
II	**L**			**Sense Organs**	**H00-H13, H15-H59, H60-H62, H68-H95**
II	L	ZA	74	Glaucoma	H40
II	L	ZA	75	Cataracts	H25-H26
II	L	ZA	76	Other visual disorders	H00-H21, H27-H35, H42-H59
II	L	ZA	77	Hernia loss and other ear disorders	H60-H62, H68-H95
II	**M**			**Cardiovascular**	**100-126, 128-184, 186-199, J81**
II	M	ZA	78	Rheumatic heart disease	I01-I09
II	M	ZA	79	Ischaemic heart disease	I20-I25
II	M	ZA	80	Stroke	I60-I69
II	M	ZA	81	Inflammatory heart disease	I30, I33, 138, I40, I42
II	M	ZA	81a	Peri- endo myocarditis	I30, I33, I38, I40
II	M	ZA	8I b	Cardiomyopathy	I42
II	M	ZA	82	Hypertensive heart disease	I10-I13
II	M	ZA	83	Non-rheumatic valvular disease	I34-I37
II	M	ZA	84	Pulmonary embolism	I26
II	M	ZA	85	Aortic aneurysm	I71
II	M	ZA	86	Peripheral vascular disorders	I72- I78, I80-I84, I86-I89
II	M	ZA	87	Other cardiovascular	I00, I28, I3I, I44-I45, I95-I99
				III-defined cardiovascular	I46-I49, I50-I5I, I70, J81
				Heart failure etc	I46-I49, I50-I51, J81
				Atherosclerosis	I70
II	**N**			**Respiratory**	**I27, J30-J80, J82-J86, J92-J99**
II	N	ZA	88	COPD	J40-J44, 127
II	N	ZA	89	Asthma	J45-46
II	N	ZA	90	Aspiration pneumonia! lung abscess/emphysema	J69, J85-J86
II	N	ZA	91	Other respiratory	J30-J39, J47, J60-J68, J70, J80, J82-J84, J92-J98
II	**O**			**Digestive**	**K20-K38, K40-K63, K65-K93, I85**
II	O	ZA	92	Peptic ulcer	K25-K28
II	O	ZA	93	Appendicitis	K35-K37
II	O	ZA	94	Noninfective gastroenteritis and colitis	K50-K52
II	O	ZA	95	Cirrhosis of liver	K70, K74, K76, I85
II	O	ZA	96	Hepatic failure	K72
II	O	ZA	97	Gall bladder disease	K80-K83
II	O	ZA	98	Diseases of the pancreas	K85 K86
II	O	ZA	99	Other digestive	K20-K22, K29-K31, K38, K40-K46, K55-K66, K71, K73, K75, K90-K91
				III defined	K92
II	**P**			**Genitourinary**	**N00-N50, N60-N64, N75-N98**
II	P	ZA	100	Nephritis/nephrosis	N00-N19
II	P	ZA	101	Benign prostatic hypertrophy	N40
II	P	ZA	102	Other genito-urinary	N20-N23, N25-N39, N41-N50, N60-N64, N75-N98
II	**Q**	**ZA**	**103**	**Skin disease**	**L00-L98**

II	**R**			**Musculo-skeletal**	**M00-M99**
II	R	ZA	104	Rheumatoid arthritis	M05-M06
II	R	ZA	105	Osteoarthritis	M15-M19
II	R	ZA	106	Other musculo-skeletal	M00-M02, M08, M10-M13, M20-M99
II	**S**			**Congenital abnormalities**	**Q00-Q99**
II	S	ZA	107	Neural tube defects	Q00-Q07
II	S	ZA	108	Cleft lip/palate	Q35-Q37
II	S	ZA	109	Congenital heart disease	Q20-Q28
II	S	ZA	110	Congenital disorders of GIT	Q38-Q45
II	S	ZA	111	Down syndrome and other chromosomal anomalies	Q90-Q99
II	D	ZA	112	Fetal alcohol syndrome	Q86.0
II	S	ZA	113	Other congenital abnormalities	Q1 0-Q18, Q30-Q34, Q50-Q56, Q60-Q64, Q65-Q79, Q80-Q85, Q87
				III defined	Q89
II	**T**			**Oral conditions**	**K00-K14**
II	T	ZA	114	Dental caries	K02
II	T	ZA	115	Periodontal disease	K05
II	T	ZA	116	Other oral health	K00-K01, K03-K04, K06-K14
II	**U**			**Cot death**	**R95, R96-R98 < 12 MTHS**
II	U	ZA	117	Cot death	R95, R96-R98 < 12 MTHS
				III defined	**R00-R09, R10-R19, R20-R23, R25-R29, R30-R39,R40-R46, R47-R49, R50-R69, R70-R79, R80-R82, R83-R94, R96-R98, > 12 months, R99**
III				**Injuries**	**V01-V99, W00-W99, X00-X99, Y00-Y98**
III	**V**			**Unintentional**	**V00-V99, W00-W99, X00-X59, Y40-Y86, Y88**
III	V	ZA	118	Road traffic accidents	V01-V04, V06, V09-V8,0 V8,7 V89, V99
III	V	ZA	119	Other transport accidents	V05, V81-V86, V88, V90-V94, V95-V98
III	V	ZA	120	Mining accidents	Y37
III	V	ZA	121	Poisoning	X40-X49
III	V	ZA	122	Surgical / medical misadventure	Y60-Y69, Y70-Y82, Y83-Y84, Y88
III	V	ZA	123	Falls	W00-W19
III	V	ZA	124	Fires	X00-X09
III	V	ZA	125	Natural and environmental factors	W53-W64, X20-X29, X30-X39, X50-X57
III	V	ZA	126	Drowning	W65-W74
III	V	ZA	127	Suffocation and foreign bodies	W75-W84
III	V	ZA	128	Other unintentional injuries specified	W20-W49, W50-W52, W85-W99, Y40-Y59, X10-X19, X58, Y38, Y39
				III defined	YB5-YB6
				III defined transport	YB5
				III defined other unintentional	X59, YB6
III	**W**			**Undetermined whether intentional or unintentional**	**Y10-Y34, Y87, Y89**
III	**X**			**Intentional injuries**	**X60-X99, Y00-Y09, Y35-Y36**
III	X	ZA	129	Suicide and self-inflicted	X60-X84
III	X	ZA	130	Homicide and violence	X85-Y09
III	X	ZA	130a	with firearm	X93-X95
III	X	ZA	130b	without firearm	X85-X92, X96-X99, Y00-Y08
III	X	ZA	131	War / Legal intervention	Y36, Y35
				III defined	Y09

8.0 REFERENCES

1. Ras GJ, Simson IW, Anderson R*, et al. Acquired immunodeficiency syndrome. A report of 2 South African cases*. S Afr Med J 1983; **64**(4):140-142.
2. Maartens G, Wood R, O'Keefe E, Byrne C. *Independent epidemics of heterosexual and homosexual HIV infection in South Africa-survival differences*. QJM 1997; **90**(7):449-454.
3. Ijsselmuiden CB, Steinberg MH, Padayachee GN*, et al. AIDS and South Africa - towards a comprehensive strategy*. S Afr Med J 1988; **73**:455-460.
4. McIntyre J. *HIV/AIDS in South Africa - a relentless progression?* S Afr Med J 1996; **86**:27-28.
5. Smith A. *HIV/AIDS in KwaZulu-Natal and South Africa*. AIDS Anal Afr 2000; **11**:6-9.
6. Botha J, Bradshaw D. *African vital statistics - a black hole?* S Afr Med J 1985; **67**:977-981.
7. Küstner HGV, Swanevelder JP, van Middelkoop A. *National HIV surveillance in South Africa 1990-1992*. S Afr Med J 1994; **84**(4):195-200.
8. Stuart J. *Under-reporting of AIDS*. S Afr Med J 1993; **83**:689.
9. Küstner HGV, Swanevelder JP, Van Middelkoop A. *National HIV surveillance in South Africa 1993-1995*. S Afr Med J 1998; **88**:1316-1320.
10. Swanevelder JP, Küstner HGV, van Middelkoop A. *The South African HIV epidemic, reflected by nine provincial epidemics, 1990-1996*. S Afr Med J 1998; **88**:1320-1325.
11. *AIDS epidemic update*. Geneva: UNAIDS; 2000.
12. Morgan D, Mahe C, Mayanja B*, et al. HIV-1 infection in rural Africa: is there a difference in median time to AIDS and survival compared with that in industrialized countries?* Aids 2002; **16**:597-603.
13. Zaba B, Whiteside A, Boerma JT. *Demographic and socioeconomic impact of AIDS: taking stock of the empirical evidence*. Aids 2004; **18**(suppl 2):S1-S7.
14. Porter K, Zaba B. *The empirical evidence for the impact of HIV on adult mortality in the developing world: data from serological studies*. Aids 2004; **18 Suppl 2**:S9-S17.
15. Urassa M, Boerma JT, Isingo R*, et al. The impact of HIV/AIDS on mortality and household mobility in rural Tanzania*. Aids 2001; **15**(2017-2023).
16. Sewankambo NK, Gray RH, Ahmad S*, et al. Mortality associated with HIV infection in rural Rakai District, Uganda*. Aids 2000; **14**:2391-2400.
17. Crampin AC, Floyd S, Glynn JR*, et al. Long-term follow-up of HIV-positive and HIV-negative individuals in rural Malawi*. Aids 2002; **16**:1545-1550.

18. Todd J, Balira R, Grosskurth H*, et al. HIV-associated adult mortality in a rural Tanzanian population*. Aids 1997; **11**:801-807.

19. Senkoro KP, Boerma JT, Klokke AH*, et al. HIV incidence and HIV-associated mortality in a cohort of factory workers and their spouses in Tanzania, 1991 through 1996*. J Acquir Immune Defic Syndr 2000; **23**(2):194-202.

20. Blacker J. *The impact of AIDS on adult mortality: evidence form national and regional statistics*. Aids 2004; **18**(S2):S19-S26.

21. Feeney G. *The impact of HIV/AIDS on adult mortality in Zimbabwe*. Popul Dev Rev 2001; **27**(4):771-780.

22. Tollman SM, Kahn K, Garenne M, Gear JS. *Reversal in mortality trends: evidence from the Agincourt field site, South Africa, 1992-1995*. Aids 1999; **13**(9):1091-7.

23. Hosegood V, Vanneste AM, Timæus IM. *Levels and causes of adult mortality in rural South Africa: the impact of AIDS*. Aids 2004; **18**(4):663-71.

24. Dorrington R, Bourne D, Bradshaw D*, et al. The impact of HIV/AIDS on adult mortality in South Africa. Technical Report.* Burden of Disease Unit, Medical Research Council. 2001 [cited 14 June 2006]; Available from: http://www.mrc.ac.za/bod/

25. Dorrington RE. *ASSA600: An AIDS model of the Third Kind?* Transactions of the Actuarial Society of South Africa 1998; **13**(1):99-153.

26. Anderson BA, Phillips HE. *Adult mortality (age 15-64) based on death notification data in South Africa: 1997-2004*. Pretoria: Statistics South Africa; 2006. Report No.: 03-09-05.

27. Groenewald P, Bradshaw D, Dorrington R*, et al. Identifying deaths from AIDS in South Africd: an update*. Aids 2005; **19**:744-745.

28. Williams B, Campbell C. *Mines, migrancy and HIV in South Africa - managing the epidemic*. S Afr Med J 1996; **86**:1249-1251.

29. Ijsselmuiden CB, Padayachee GN, Mashaba W*, et al. Knowledge, beliefs and practices among black goldminers relating to transmission of human immunodeficiency virus and other sexually transmitted diseases*. S Afr Med J 1990; **78**:520-523.

30. Evian C, Fox M, MacLeod W*, et al. Prevalence of HIV in workforces in southern Africa, 2000 - 2001*. S Afr Med J 2004; **94**:125-130.

31. Stevens W, Apostolellis A, Napier G*, et al. HIV/AIDS prevalence testing - merits, methodology and outcomes of a survey conducted at a large mining organisation in South Africa*. S Afr Med J 2006; **96**:134-139.

32. Corbett EL, Churchyard G, Charalambos S*, et al. Morbidity and mortality in South African gold miners: impact of untreated disease due to human immunodeficiency virus*. Clin Infect Dis 2002; **34**:1251-1258.

33. Glynn JR, Sonnenberg P, Nelson G*, et al. Survival from HIV-1 seroconversion in Southern Africa: a retrospective cohort study in nearly 2000 gold-miners over 10 years of follow-up*. Aids 2007; **21**:625-632.

34. Moore D. *The AIDS threat and the private sector*. Aids Analysis Africa 1999; **9**:1-2.

35. *International Statisitical Classification of Diseases and Related Health Problems, tenth revision*: World Health Organisation; 1993.

36. WHO. *Interim proposal for a WHO staging system for HIV infection and disease*. Wkly Epidem Rec 1990; **65**:221-224.

37. Bradshaw D, Groenewald P, Laubscher R*, et al. Initial burden of disease estimates for South Africa, 2000*. Cape Town: South African Medical Research Council; 2003.

38. Stata Statistical Software, Version 8. 2005. StataCorp. College Station, TX

39. Bradshaw D, Nannan N, Laubscher R*, et al. South African National Burden of Disease Study 2000: Estimates of Provincial Mortality*. Cape Town: South African Medical Research Council; 2004.

40. Dorrington R, Bradshaw D, Bourne D. *Two steps forward, one step back: Comment on adult mortality (age 15-64) based on death notification data in South Africa for 1997-2001*. S Afr Med J 2006; **96**:1028-1032.